The present invention accomplishes this result in part by the use of one or more preformed sacrificial guides. The preformed sacrificial guide cooperates with a pilot in the much larger soil processing tool to assure that the larger tool remains centered and bores downwardly in essentially a perfectly vertical path. By using the preformed sacrificial guide, large arrays of soil cement columns may be formed in processing large volumes of underground earth sites. In many of these large underground sites, it is critical that the entire volume of the underground site be either solidified into a rather solid soil cement mixture or thoroughly processed to assure a uniform result. For example, for support of an airport runway, the underground material beneath the runway must have uniform strength. As another example, in treating a large underground radioactive plume, it is critical that the entire volume of the plume be solidified or otherwise treated to minimize future movement of the radioactive materials in underground water tables.

The present invention also provides for the first time a method for forming soil-cement columns of any diameter that have very precise verticality and precise centering. This high degree of precision is achieved by using a sacrificial guide to position and guide the soil processing tool.

The present invention contemplates the use of some aspects of my prior patents, including U.S. patents 4,793,740; 4,958,962; 5,396,964; 6,183,166 and 6,241,426, all of which are incorporated by reference as though set forth in full herein.

Portions of those prior patents are utilized in conjunction with the present invention and some significant portions of those prior patents will be described herein as they pertain to the present invention.

The overall concept of the present invention is to first form a sacrificial guide with a soil cement mixture and allow the guide to harden sufficiently to act as a pilot for a larger soil processing tool. The pilot shaft of the larger soil processing tool is centered in and guided by the preformed sacrificial guide as the large processing tool begins moving downwardly. As

the soil processing tool moves downwardly, its heavy, rotating teeth break up and fragment the sacrificial guide into soil cement particles so that the soil cement mixture utilized to form the sacrificial guide is eventually interspersed into the much larger soil cement column formed by the large scale processing tool. The result is a precisely placed, large diameter and homogeneous soil cement column. An array of such columns can be placed very accurately in order to solidify or otherwise process very large underground sites.

The sacrificial guide may be either a hollow or a solid cylinder and formed, for example, by the technique taught in my U.S. patent 6,183,166. If the sacrificial guide is hollow, the pilot of the larger soil processing tool is centered and guided by the hollow sacrificial guide. If the sacrificial guide is a solid cylinder, it has a relatively soft center and a relatively hard outer region. In this embodiment, the larger soil processing tool has a pilot which is tipped with an auger. The auger drills out the soft center of the guide, but is simultaneously centered and guided by the hard, outer region of the guide.

A primary object of the invention is to provide a method for hardening or solidifying large volumes of material located in a subterranean earth situs so that the earth situs may be used to support structures carrying large loads such as airport runways.

Another object of the invention is to provide a method for forming underground soil-cement columns of any diameter wherein the columns are formed by using a sacrificial guide and the resultant columns have a higher degree of verticality and more precise centering than known in the prior art.

A further object is to provide a method of forming underground soil-cement columns utilizing a soil-cement sacrificial guide, wherein the guide becomes broken up and fragmented to form a part of the resultant soil-cement column.

Another object of the invention is to provide a method for forming a sacrificial guide which centers and guides a large diameter soil processing tool having a diameter of more than 8 feet which can be controlled and guided to form precision vertical soil-cement columns

centered at precise locations.

A further object is to provide a method for hardening or solidifying large subterranean volumes of material wherein an array of sacrificial guides is formed and those sacrificial guides are used to guide and control large diameter soil processing tools to form soil-cement columns in the situs.

Other objects and advantages of the invention will become apparent from the following description of the drawings wherein:

Brief Description of the Drawings

Fig. 1 illustrates a small diameter soil processing tool forming a soil-cement column as it advances downwardly and forms a hole by mechanically and hydraulically dividing the material in the hole created by the tool;

Fig. 2 illustrates the auger shaped soil processing tool as being withdrawn and vigorously rotated to form a relatively hard outer casing and relatively soft inner portion of the soil-cement column;

Fig. 3 illustrates the soil-cement column having an outer relatively hard region and an inner relatively soft region;

Fig. 4 shows the hole after the soil-cement has been allowed to set up;

Fig. 5 illustrates one embodiment of the invention wherein the softer center region has been drilled out to form a hollow underground casing;

Fig. 6 illustrates the introduction of a very large soil processing tool having a pilot wherein the pilot is centered by and guided by the hollow underground casing illustrated in Fig. 5;

Fig. 7 illustrates a large soil-cement column left by the large diameter soil processing tool after it has been withdrawn;

Fig. 8 illustrates an array of sacrificial guides which have been laid out in a grid-like pattern;

Fig. 9 illustrates schematically the diameter of large soil-cement columns 150 to be formed using the casings 30 as sacrificial guides;

Fig. 10 illustrates one method of hardening or solidifying the interstitial spaces between large soil-cement columns illustrated in Fig. 9;

Fig. 11 illustrates an alternate array of sacrificial guides wherein the centers of any three adjacent sacrificial guides form an equilateral triangular;

Fig. 12 illustrates an embodiment of the invention intended to solidify or harden or otherwise process virtually 100% of the soil in the subterranean earth situs being treated; and

Fig. 13 illustrates an alternate embodiment using a solid cylindrical sacrificial guide.

Detailed Description of the Drawings

Figs. 1-5 show the formation of the sacrificial guide using essentially the technology shown and described in U.S. patent 6,183,166 dated February 6, 2001. Certain portions of that disclosure are repeated herein for reference.

As shown in Figs. 1-3, a small diameter soil processing tool 10 is provided having a hollow stem 11, a first stage 85 and second stage 90. As used herein and in the claims, the phrase "small diameter" means a diameter of tool 10 between 1 and 5 feet. First stage 85 has four helical flights 12,13,14 and 15 and cutting tip 16. Cutting tip 16 typically has cutting teeth known in the art; cutting teeth are not shown in the drawings for clarity. Helical flights 12-15 are preferably as shown and described in greater detail in Fig. 12 of U.S. patent 5,396,964, owned by the assignee of the instant application. U.S. patents 5,396,964; 4,793,740 and 4,958,962 are hereby incorporated by reference as if set forth in full. The second stage 90 has four helical flights 92,93,94 and 95. The outer diameter of helical flights 12-15 of the first stage 85 is smaller than the outer diameter of helical flights 92-95 of second stage 90. The second stage 90 has a wear resistant cutting surface 96 similar to cutting tip 16 and nozzle 97 through which cement slurry is pumped.